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The Biologic and Economic Assessment of Propoxur

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THE BIOLOGIC AND ECONOMIC ASSESSMENT OF PROPOXUR

Report of the Propoxur Assessment Team

Submitted to the
U.S. Environmental Protection Agency
March 1992

Edited by
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U.S. Environmental Protection Agency

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We dedicate this document to Dr. Jeff P. LaFage, in memory of his outstanding urban entomological research and education efforts.

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EXECUTIVE SUMMARY

This report was a joint project of the U.S. Department of Agriculture, State Land-Grant Universities, and the U.S. Environmental Protection Agency. It was prepared by a team of scientists to provide sound, current scientific information on the benefits of propoxur as well as to present a discussion of alternative insecticides. This document is a scientific presentation to be used as part of the benefits and risk analysis for the Special Review Process required by the Federal Insecticide, Fungicide, and Rodenticide Act.

Propoxur is a widely used carbamate insecticide, frequently used by homeowners in aerosol formulations. It is also available in several formulations for application by professional pest control operators (PCO's). It is one of the most broadly labeled pesticides, with 321 different "sites" listed on the label. Propoxur controls a wide range of arthropod pests, both indoors and outdoors. While there are competing insecticides in other classes of chemicals, propoxur is recognized as the most active carbamate insecticide available to both PCO's and to homeowners. On some pest species, such as ticks (Ixodidae), propoxur has proven to be the most effective pesticide currently available.

Although propoxur usage decreased when pyrethroids came into broad usage, propoxur's unique qualities continue to make it an effective tool in pest control. Propoxur comprises only about two percent of total pesticide use by PCO's. However, due to availability, effectiveness, and safety, a high percentage of household pesticides contain propoxur. German cockroaches (*Blattella germanica* [Linneaus]) have become resistant to both propoxur and chlorpyrifos in some locations; however, both chemicals are still effective in most locations.

A rotation using propoxur, pyrethroids, and a phosphate-type of insecticide should delay the development of resistance. Propoxur is an indispensable insecticide in this rotation procedure. It is also very effective in controlling certain species of malathion-resistant mosquitos in California. In addition, propoxur baits have proven effective in controlling some species of otherwise hard to kill mole crickets (Gryllotalpidae) in lawns and turf farms. Although it is not always the pesticide of choice due to its high cost, propoxur is effective against lawn pests such as chinch bugs (*Blissus leucopterus* [Say]) and sod webworms (Pyralidae).

Because of propoxur's numerous site usages, its value in the rotation process, and its special value in combatting certain stubborn insect species such as ticks, fleas, and the German cockroach, the propoxur assessment team strongly recommends that propoxur be reregistered. The team also recommends maintaining the same sites for propoxur.

INTRODUCTION

Jack L. Bagent

The purpose of this report is to provide information about biologic, economic, and use information pertaining to propoxur. Title 40 CFR 162.11(a)(3) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended, directs the Environmental Protection Agency (EPA) to issue a notice of Rebuttable Presumption Against Reregistration (RPAR), which is now known as the Notice of Special Review. Mobay Chemical Corporation received a data call for Propoxur on December 21, 1987 (EPA, 1987d). Mobay decided to defend "inside" and animal uses of propoxur only, including immediate perimeter uses around structures. In 1988 the USDA Extension Service put together a propoxur assessment team comprised of Extension, research, and industry personnel to begin developing this report.

Propoxur is a general-use carbamate insecticide produced in the following formulations: emulsifiable concentrates, wettable powders, granular baits, pressurized liquids, ready-to-use liquids, dusts, and impregnated pet collars and strips. Propoxur is registered for the following sites: domestic dwellings, commercial establishments, commercial transportation vehicles, agricultural premises, ornamentals, aquatic sites, wood structures, and mosquito control sites. It is also applied directly on pets and in their living quarters.

Propoxur usage data from this study indicates most usage of this compound is in and around domestic dwellings and commercial establishments, and is applied by both commercial applicators and homeowners. A large percentage of propoxur (95 percent) is used in formulations that are specifically developed for these uses. The term "domestic dwellings" (indoor) refers to indoor areas of single family homes, mobile homes, townhouses, condominiums, and apartments. The remaining 5 percent of propoxur is used for animal research facilities, poultry houses, and garbage cans.

Propoxur has over 300 use sites on its label. These sites include livestock barns and premises, poultry and poultry houses, animal research facilities, zoos, domestic dwellings (both indoor and outdoor), garages, patios, kitchen areas, hotels, and motels. Propoxur registrations also include commercial usages such as commercial transportation facilities, aircraft, buses, boats, ships, railroads, box cars, trucks and trailers, automobiles, food-processing plants, storage areas, mills, restaurants, and food-marketing areas. The only insecticides besides propoxur that approaches this number of site uses are cyfluthrin and chlorpyrifos.

Propoxur is still considered an outstanding and effective household insecticide. Its higher cost compared to alternative insecticides has led to a general reduction in its use; however, its efficacy continues to compare very favorably with the newer competitive products. Another characteristic that tends to make propoxur less desirable than other insecticides used for the same purpose is a short shelf life of the EC formulation due to "settling out." Because propoxur is a carbamate insecticide, it is highly effective on non-carbamate resistant populations of the German cockroach. Propoxur is also highly effective for tick and flea control.

For public health, sanitation, and aesthetic reasons, insect control will continue to be considered essential in home, industrial, and public areas. Propoxur, or an alternative insecticide, will be used in these environments. Therefore, maintaining the registration of a broad range of safe and effective insecticides, such as propoxur, is essential in allowing pest control operators to make effective pest management decisions.

Insects and other arthropods have the proven potential to transmit many diseases in households, hospitals, cafeterias, and other sites. Arthropod-borne pathogens include Staphylococcus, Salmonella, and other organisms that cause digestive disorder illnesses. Most Americans demand that their home be pest-free and consider even the occasional insect intruder to be unsightly and highly undesirable. Insect-infested restaurants are perceived as substandard and may be closed following health inspections. The important role that pesticides like propoxur play in the elimination and control of anthropod-born diseases is poorly understood by Americans today.

For many household pests, there are several alternative insecticides. In the case of fleas, ticks, and the German cockroach (particularly in restaurants and food preparation areas) there exist only limited alternatives. With the increasing development of insect resistance to pyrethroids, it is even more important to maintain the continued registration of propoxur.

DESCRIPTION OF CHEMICAL

Common name:	Propoxur (BSI, ISO, ESA)
Chemical name:	2-isopropoxyphenyl methylcarbamate (IUPAC) 2-(1-Methylethoxy)phenyl methylcarbamate (CA) o-isopropoxyphenyl methylcarbamate
CAS Registry No.:	114-26-1
Other names:	PHC (JMAF); aprocarb (BSI formerly)
Trade name:	Baygon (Bayer) Blattanex (Bayer) BAY 39007 Propion Unden (Bayer) Suncide (Bayer) Rhoden (Agrotec) Pillargon (Pillar) Propogon (Crystal) Sendran
Chemical family:	Carbamate
Molecular formula:	$C_{11}H_{15}NO_3$
Molecular weight:	209.25
Physical form:	Colorless crystals
Melting point:	84-87°C.
Vapor pressure:	1.3 PA at 120°C.
Specific gravity:	1.12 at 20°C.
Stability:	Hydrolyzed by strong alkalis
Corrosiveness:	Non-corrosive
Solubility:	In water at 20°C, ca. 2 g/l. Soluble in most organic solvents, for example: alcohols, acetone, methyl ethyl ketone, cyclohexanone, dichloromethane, chloroform.
Mode of Action:	Non-systemic insecticide with contact and stomach action. Cholinesterase inhibitor. Gives rapid knockdown, and has long residual activity.
Uses:	Control of cockroaches, flies, fleas, mosquitoes, millipedes and other insect pests in food storage area, houses, animal houses, etc. Control of sucking and chewing insects (including aphids) in fruit, vegetables, ornamentals, vines, maize, lucerne, soybeans, cotton, sugar cane, rice, cocoa, forestry, etc.
Phytotoxicity:	Chrysanthemums, carnations, and hydrangeas may be injured at higher dose rates. Blossom thinning may occur on fruit trees.
Formulation types:	Wettable powder Emulsifiable concentrate Dustable powder Fumigant Aerosol Bait (ready for use)
Mixed formulations:	Propoxur in combination with one or more of the following chemicals: dichlorvos methiocarb pyrethrins cyfluthrin + dichlorvos azinphos-methyl
Compatibility with other products:	Compatible with most common insecticides and fungicides. Mixtures with alkaline substances should be applied immediately after preparation of the spray mixture.
Manufacturers:	Bayer AG; Mobay Corporation Agrichem Division; Pillar International Company; Sankyo Crystal Chemical InterAmerica; Taiwan Tainan Giant Industrial Co., Ltd

SURVEY METHODS USED IN THIS ASSESSMENT

Jack L. Bagent

To determine propoxur usage, three specific surveys were developed for this assessment. The first was a survey instrument mailed to Extension entomologists and veterinarians across the United States. Instructions with the survey instrument encouraged State scientists to contact users in their State to develop and report site and pest usage patterns and the amount of propoxur used. These data are strongest in determining use patterns, but other methods are needed to determine quantities of propoxur used by various industries. Inquiries presented in the survey instrument to State scientists included: which pests propoxur was used on; the extent of propoxur usage; the methods and rate of application; and the available alternatives for propoxur.

To obtain an estimate of total propoxur usage, local pesticide distributors in several States were contacted to determine the amount of propoxur sold from 1986 to 1988. These distributors were also asked to provide an estimate of the increase or decrease in the sale of propoxur during this time. In all cases the distributors indicated a decrease in the sale of propoxur, beginning about 1984. Sales of propoxur continued to decline each year thereafter. The distributors indicated that pest control operators in general are presently using considerably less propoxur, and that pyrethroids now constitute a large share of this market. Usage data were returned by 24 States.

A second survey instrument was developed for distribution to homeowners. The purpose of this survey was to determine how many cans of pressurized insecticides were used per household per year. This survey was conducted by mailouts to individual homeowners in selected States. In other States, the surveys were done though homemaker clubs, where the survey sheets were taken to the individual clubs and filled out by the homemaker members. The questionnaire consisted of questions pertaining to whether the survey recipient lived in an urban or rural setting, the type of insect that was being controlled, how the insecticide was to be applied, how many times during the year this particular brand of insecticide was applied, and what the particular formulation was.

The third method of surveying was performed by the National Pest Control Association and State pest control associations to determine how much propoxur was used by licensed pest control operators nationwide. These data proved to be very useful because they indicated that PCO's were not greatly concerned about propoxur. With newer household insecticides on the market, PCO's felt that propoxur was not as essential as it had been earlier. In addition, an attempt was made to determine whether propoxur use had increased or decreased during the past five years.

After tabulating the data, the assessment team members reviewed the replies for consistency and overall validity. Some follow-up calls were made to clarify responses to specific survey questions. Final estimates reflected the expertise of individuals in the field as well as the professional judgement of the assessment team members and other Extension entomologists nationwide.

RISK STUDIES RELATED TO PROPOXUR

Jim Criswell and Dave Brassard

Chronic Toxicity: Principal analysts of this risk section were Yvette Hopkins, economist, and Dave Brassard, entomologist. This section was completed on September 15, 1989. Permanent behavioral changes were reported in rats that received propoxur repeatedly. However, no effect was seen in experimental rats exposed to 7.5 mg/day for 28 days (as part of a chronic oral study (Gosselin et al., 1984; American Conference of Governmental Industrial Hygienists, Inc., 1986). Propoxur was very efficiently detoxified, or made into non-poisonous forms, thus making it possible for rats to tolerate approximately one LD_{50} of the insecticide per day for long periods; this was provided that the insecticide was spread out in the food and eaten over the whole day, rather than a single ingestion in a brief period (Hayes, 1982).

A three-month exposure of rats to dietary levels of 800 ppm did not affect growth rate, cholinesterase levels, or food consumption (American Conference of Governmental Industrial Hygienists, Inc., 1986). In two-year feeding trials, male and female rats receiving 250 mg active ingredient/kg body weight showed no ill effect. At 750 mg/kg, the liver weight of female rats increased; otherwise, there was no ill effect (Worthing, 1983).

Reproductive Effects: Propoxur had adverse effects on newborns of female rats that were given oral doses of 1,600 mg/kg between the 6th and 15th day of pregnancy, and the 15th day after birth (National Institute for Occupational Safety and Health, 1986). Normal reproduction occurred in female rats, given a dietary level of 6,000 ppm of propoxur as part of a three-generation reproduction study. However, the size and growth of the litter was reduced, and food intake, growth, and lactation was depressed in parents (Hayes, 1982). The EPA fact sheet (EPA, 1987b) on propoxur states that no known studies indicate reproductive effects occurring because of propoxur.

Teratogenic Effects: A growth reduction was observed in the offspring of pregnant rats given experimental dosage levels of 1,000, 3,000, and 10,000 ppm of propoxur. No teratologic abnormalities were observed. At 10,000 ppm, however, there was a decrease in the number of fetuses produced. In two strains of mice 31 mg/kg caused some embryotoxicity, or poisoning of embryos, when propoxur was injected into their abdominal cavities intraperitoneally (such as by stomach tube). Dosages of 10 mg/kg did not produce any teratogenic effects (Hayes, 1982).

Schuluster and Lorke (1981) studied the effect of propoxur on Himalayan CHBB:HM rabbits during gestation. No adverse effects were observed in the dams, and no changes were detected in the implantation index, mean placental weight, resorption index, or litter size. Embryos were examined for visceral and skeletal defects grossly and stained with alizarin. Transverse sections were then prepared using the Wilson technique. No adverse fetal effects were found at any dose level with respect to mean fetal weight, percent of stunting, percent of slight skeletal deviations, or malformation index. The NOEL for maternal toxicity, teratogenicity, and fetotoxicity was greater than 10 mg/kg/day (the highest dose tested).

Mutagenic Effect: Propoxur did not cause mutations in six different types of bacteria (Hayes, 1982). The same results were obtained by DeLorenzo et al. (1978), Moriya et al. (1983), and Blevins et al. (1977) for mutagenic test using the mutagenicity test of Ames. A derivative of propoxur (N-nitros) is mutagenic (Hallenbeck and Cummingham-Burns, 1985).

Carcinogenic Effects: Bomhard and Loeser (1981) conducted a 2-year feeding study on mice. Gross and histological examinations of tissues revealed no evidence of increased tumor frequency at dose levels of 0, 700, 2,000 and 6,000 ppm. However, EPA's operating procedures have classified propoxur in GROUP B2 (probable human carcinogen) (EPA, 1987a).

Organ Toxicity: Propoxur administered as a single dose of 1.5 mg/kg (95 percent active ingredient) to a 42-year-old male volunteer resulted in about 45 percent of the dose being recovered in urine within 24 hours as 2-isopropoxyphenyl. Since vomiting occurred 23 minutes after ingestion, the authors assumed that much of the dose was expelled by this route--therefore, the percent actually absorbed could not be calculated (Vandekar et al., 1971). Dawson et al. (1964) conducted similar studies and found 2-isopropoxyphenyl in the urine.

Propoxur is broken down and excreted rapidly in urine (American Conference of Governmental Industrial Hygienists, Inc., 1986; Morgan, 1982). Exposure to this insecticide can be monitored by determining the urinary excretion of one of its breakdown products (American Conference of Governmental Industrial Hygienists, Inc., 1986). Dawson et al. (1964) reported that for humans given a single oral dose of 92.2 mg propoxur (purity not specified), 38 percent of the dose was excreted as phenols in urine over a 24-hour period. Most of the dosage was excreted in the first 8 to 10 hours..

Health Effects: Vandekar et al. (1971) studied the acute oral toxicity in human volunteers. A 42-year-old male ingested a single oral dose of 1.5 mg/kg of propoxur (95 percent active ingredient). Cholinergic symptoms--including blurred vision, nausea, sweating, tachycardia, and vomiting--began about 15 to 20 minutes after exposure. Effects were transient and disappeared within two hours. Cholinesterase (ChE) activity in red blood cells decreased to 27 percent of control values within 15 minutes after exposure and returned to control levels within two hours. No effect was detected in plasma ChE activity.

Another test involving a dose of 0.36 mg/kg caused short-lasting stomach discomfort, blurred vision, and moderate facial redness and sweating. Red blood cell ChE activity fell to 57 percent of control values within 10 minutes, then returned to control levels within three hours. Vandekar et al. (1971) administered five oral doses of 0.15 or 0.20 mg/kg to male volunteers at half-hours intervals (total dose of .75 or 1.0 mg/kg). In each subject, a symptomless depression of red blood cell ChE was observed; the lowest level, about 60 percent of control values, was reached between one and two hours following doses 3, 4, and 5 mg/kg. After the final dose, red blood cell ChE activity rose to control levels within two hours. The authors noted that a dose of propoxur was tolerated better if it was given over time than as a single dose. EPA designated a ten day Health Advisory for a 10kg child as 0.040 mg (EPA, 1987b).

<u>Long Term</u>: Davies et al. (1967) described the effects of a large scale spraying operation in El Salvador where propoxur (OMS-33, 100 percent active ingredient) was used. The total amount of OMS-33 sprayed was 345 kg. Among applicators, exposure (expressed in person-days) was 70.5; 19 experienced symptoms (26 percent incidence). In the general population exposure was 3,340 person-days. Thirty-five experienced symptoms (1 percent incidence). The primary symptoms were headache, vomiting, and nausea. Applicators symptoms occurred mostly in the first days, with no visible symptoms after that time. EPA has designated a life time Health Advisory of 0.003 mg (EPA, 1987b).

Metabolism in Laboratory Animals: Dietary levels of 1,000 and 2,000 ppm of propoxur in rats depressed cholinesterase activity in the brain and blood, and also caused some cellular changes in the liver (Hayes, 1982). Everett and Gronberg (1971) studied the metabolism of propoxur in

Holtzman rats. Animals were dosed by gavage, with propoxur (5 to 10 mg/kg) labeled with 14C or 3H in the carbonyl or isopropyl groups. Results indicated that the major pathway of propoxur metabolism involved depropylation to 2-hydro-xyphenyl-N-methyl carbamate and hydrolysis of the carbamate to isopropoxyphenyl. Minor pathways involved ring hydroxylation at the five- or six-position, secondary hydroxylation. Metabolites that contained the 6-hydroxy group formed N-conjugates, while those that contained the 5-hydroxy group formed O-glucuronides. Eighty-five percent of the orally-administered propoxur was recovered from the rats within 16 hours.

Krishna and Casida (1965) administered single oral doses of 14C-labeled propoxur (50 mg/kg) to Sprague-Dawley rats. After 48 hours about 4 percent of the dose had been excreted in feces and the remainder was detected in urine (64 to 72 percent), expired air (26 percent), or body (4.2 to 7.9 percent). This indicated that propoxur was well absorbed (at least 96 percent) from the gastrointestinal tract.

Similar findings were reported by Foss and Krechniak (1980). Foss and Krechniak (1980) administered 50 mg/kg to male albino rats orally. Analysis of tissues indicated that propoxur levels were greatest in the kidneys, with somewhat lower levels in the liver, blood, and brain. For long-term exposure, Suberg and Loeser (1984) and Loeser (1968a) found no observable effect level (NOEL) of 200 ppm and 250 ppm respectively.

Bomhard and Loeser (1981) concluded from their studies that clinical chemistry and blood studies were within the normal range for all groups, and there were no significant gross pathological or histopathological findings that could be attributed to the ingestion of propoxur. They concluded that male mice tolerated the pesticide at levels up to and including 2,000 ppm, while female mice tolerated doses up to and including 6,000 ppm without adverse effects and a NOEL of 2,000 ppm.

Wildlife Risk Studies: Propoxur is toxic to wildlife (Mobay Chemical Corporation, 1982). The oral LD_{50} for bullfrogs is 595 mg/kg. For mule deer it is 100 to 350 mg/kg when the animals were fed orally in capsules (Hudson et al., 1984). Birds feeding on propoxur in treated areas may be killed (Thompson, 1985). The toxicity of propoxur varies by type of bird: propoxur's oral LD_{50} in chickens is 47 mg/kg; in wild birds 4 mg/kg; and in ducks 10 mg/kg (National Institute for Occupational Safety and Health, 1986).

Acute symptoms of propoxur poisoning in birds include: eye tearing, salivation, muscle incoordination, diarrhea, and trembling. These signs appear within five minutes of exposure. Propoxur poisoning deaths occurred between 5 and 45 minutes or overnight; symptoms in survivors disappeared from 90 minutes to several days after treatment (Hudson et al., 1984). Propoxur is toxic to fish, as well as other animals that eat fish (Hartley and Kidd, 1983). The 48-hour LC_{50} for fathead minnows is 19 ppm (McEwen and Stephenson, 1979).

Propoxur is also highly toxic to honey bees (*Apis mellifera* Linneaus) (Worthing, 1983); the LD_{50} is greater than one ug/honeybee (Kuhr and Dorough, 1976). Severe bee losses may be expected if propoxur is used when bees are present, either at treatment time or within a day after treatment (Morse, 1987).

Environmental Fate: The breakdown of propoxur in soil and water is accelerated by alkaline conditions (Thompson, 1985). While there was practically no loss of propoxur formulation from silt-loam soil when the insecticide was applied during a six-month period, 25 percent of applied propoxur was lost from sand within 100 days (McKenzie, 1974). It hydrolyzes at a rate of 1.5 percent in a 1 percent aqueous solution at a pH of 7 (Hartley and Kidd, 1983). Propoxur has not been found in any of the 58 ground water samples analyzed from 55 locations (EPA, 1987b).

Propoxur is generally not phytotoxic. Crop tolerance is good for recommended areas of use (Harding, 1979).

Applicator and Worker Exposure to Propoxur (Pest Control Operators): The total time spent per house per applicator is 20 minutes, with about 5 to 10 minutes of that time spent actually spraying. For apartments, the average time per apartment was 15 minutes, with an average of about 7 minutes being spent applying the pesticide. Other information gathered in relationship to exposure to the applicator included five minutes for refilling the sprayer and 1.5 minutes for pumping up the sprayer. The average applicator worked approximately 5 to 8 hours per day, or approximately 220 work days per year.

The average applicator, therefore, would use approximately three gallons of finished product per day, both in houses and apartments, for a total of about 660 gallons per year. In addition, each applicator would spray approximately 16 houses, or about 24 apartments per day, with a total number of 3,520 houses or 5,280 apartments sprayed per year. Applicators would then spend 15 minutes per day refilling the sprayer for a total of about 3,300 minutes per year. In addition, workers would spend four minutes and 50 seconds per day, or 990 minutes per year pumping up the sprayer--with an average of 5.6 hours on-site per house and 6.3 hours on-site per apartment--for a total of 1,288 hours in houses per year or 1,391 hours in apartments per year.

Using these data, we can accurately determine the cost of the insecticide per house and apartment, and determine how much exposure time each applicator would have per year for the particular pesticide being used. This is assuming that all of this time was spent by the worker applying one particular pesticide--in this case, propoxur. However, for all practical purposes, only a small percentage of this time was spent applying propoxur. Based on current data available to us, PCO's apply propoxur for approximately two percent of their time.

Information was furnished by E. David Thomas (Section Chief of the Entomology Section, U.S. Environmental Protection Agency) to determine the amount of propoxur utilized per house or apartment. These data indicated approximately 80 percent of the household insecticides were applied in kitchen and bathroom areas, and 20 percent was applied in other areas of the house. The apartment data was very similar--about 82 percent of the insecticide was used in the apartments' kitchens and bathrooms. Approximately 18 percent of propoxur was used in the remaining areas of the apartments.

Thomas' report also indicated that an average of approximately 1.5 pints of finished [i.e., Ready-To Use (RTU)] spray product was used per house, and about 1.0 pints of finished spray was used per apartment. Based on the labeled rates, this would equate to 0.131 ounces used per house, and about 0.088 ounces active ingredient used per apartment per application. Breaking this down further per year, each house would receive about 250 linear feet finished spray, and each apartment would have about 228 linear feet finished spray per year.

ALTERNATIVES TO PROPOXUR

Jack L. Bagent

Several insecticides could serve as alternatives to propoxur. However, few of these have the extensive labeling and site application labels that propoxur possesses. Propoxur continues to provide excellent control of the German cockroach, fleas, and ticks in most areas of the United States. Propoxur, since it is a carbamate insecticide, can serve as a reliable product to rotate in a pest management program to delay resistance development in household pests.

Insecticides available as alternatives for propoxur are cypermethrin, fenvalerate, permethrin, cyfluthrin, diazinon (including encapsulated formulations), chlorpyrifos, acephate, bendiocarb, methoprene, fenoxycarb, pyrethrins, and various formulations of boric acid. A short commentary on some of these products and their usages follows:

Cypermethrin: Cypermethrin is a household insecticide in the pyrethroid group. It is considered to be one of the most effective household insecticides presently labeled. According to Nolan (1989), it constitutes approximately 40 to 50 percent of the insecticide being used by pest control operators, both for commercial accounts and in homes.

Cypermethrin has broad spectrum control, and at this time is very effective against most of the common household insects (except fleas). However, the label on cypermethrin does not include food preparation areas or the breadth of other sites that are presently listed for propoxur. Therefore, cypermethrin has limited replacement potential for propoxur. Efficacy data indicates that cypermethrin is effective against the same groups of insects as propoxur. Cypermethrin provides long residual pesticide activity when used indoors.

Permethrin: Permethrin is a pyrethroid insecticide labeled for certain household uses. A popular formulation is in pressurized cans. Pest control operators use very little of this insecticide since it requires higher concentrations than cypermethrin or cyfluthrin for reliable pest control.

Fenvalerate: Fenvalerate has some household use labels, including cockroaches and other pests found in the house. However, it does not have wide acceptance, and sees only limited usage.

Cyfluthrin: Cyfluthrin has the most similar site use labels to propoxur of any of the alternative pesticides. Cyfluthrin has numerous sites where it can be applied, including food processing and handling areas, and is the only pyrethroid that has this type of site labeling. Cyfluthrin is effective against a broad spectrum of insects and other arthropod pests in households and commercial establishments. However, in many areas of the country, German cockroaches are demonstrating resistance to pyrethroids. Resistance to pyrethroid insecticides will occur rapidly if alternative chemistry is not available. Therefore, it is imperative that pest control operators and homeowners have insecticides with different chemistries and modes of action to use in rotation with the pyrethroids.

Chlorpyrifos: Chlorpyrifos is an organophosphate insecticide that is effective against many household pests. The German cockroach and fleas, as well as other pests chlorpyrifos is labeled for, are effectively controlled by this insecticide. However, the sites where chlorpyrifos is registered are more restricted than propoxur and cyfluthrin. As an organophosphate insecticide, chlorpyrifos is an important alternative for rotation in order to delay the development of pesticide resistance to any one family of insecticides.

Diazinon: Diazinon is an organophosphate insecticide and has been registered longer for household pest control longer than the other alternatives. Diazinon has broad spectrum usage and a number of site uses, but it does not have the extensive site usage labels that propoxur and cyfluthrin have. Diazinon is less effective than it was 20 years ago against certain pests, particularly the German cockroach and fleas.

Bendiocarb: This insecticide has a similar chemistry to propoxur because it is also a carbamate. However, bendiocarb is not as effective against the German cockroach, fleas, or ticks as propoxur. Also, bendiocarb does not have as extensive site use labeling as propoxur, and therefore, it is a limited alternative to propoxur.

Acephate: Acephate is an organophosphate insecticide and can serve as an alternative to propoxur against some pests and in certain sites. However, acephate does not have the broad range of site uses as propoxur, such as in food handling and processing areas, and can only be considered a limited alternative. In addition, acephate has a strong and offensive odor, which can persist for several days after application.

Methoprene and Hydroprene: Methoprene and hydroprene are growth regulators and in some areas they are effective against certain insects. Immature fleas and cockroaches are controlled well by these compounds. These materials can serve as a partial replacement for propoxur. However, neither compound is an adulticide. They only affect the developing immature stages, and must be used in conjunction with an insecticide directed at control of the adult stages of the pest.

Boric Acid: Boric acid is an inorganic acid that can be used as an insecticidal alternative to propoxur in specific use patterns. Boric acid is effective against certain household insects, including all of the cockroaches. However, boric acid is not an alternative for such insects as silverfish (*Lepisma saccharina* Linneaus), fleas, and ticks.

There are some advantages to using boric acid, since it can be used in places where children might be exposed to a synthetic-type of insecticide. It is also an important alternative for people who want to use a non-synthetic insecticide. If given enough time, boric acid is very effective against cockroaches. The disadvantages of the compound are that it is slow to work (it takes one to six months to reduce a large population of cockroaches down to an acceptable population density) and the white powdery residue is considered by some to be unsightly.

Propetamphos: Propetamphos is a highly effective phosphate insecticide that is popular with pest control operators for fleas and German cockroach control. Propetamphos is also effective against several other household arthropod pests. It does not have the extensive site-use labels of propoxur. Also, there are no homeowner uses of this compound--it is restricted for professionals use only. Therefore, for PCO's it is a suitable alternative to propoxur for pest control, but not for homeowners.

Nonchemical Alternatives to Propoxur for Household Insect Control: A great deal of emphasis should be placed on sanitation and cleanliness in managing household insects; however, this effort alone will not eliminate the need for chemical pest control. Research studies have shown that no matter how clean a kitchen is kept, there exists a residual food supply sufficient to maintain a large population of German cockroaches (Bennett, 1988). In restaurants, hotels, and food warehouses sanitation might be excellent, yet cockroaches can increase to large populations. German cockroaches are inadvertently reinfested into homes from grocery stores and warehouses in packing boxes, thus making it impossible to keep these insects out by sanitation alone. Sanitation, cleanliness, and exclusion are helpful in managing household pests, but do not offer an alternative for addressing an existing infestation.

PROPOXUR USAGE IN HUMAN DWELLINGS, INDUSTRIAL AND INSTITUTIONAL AREAS (EXCEPT FOOD HANDLING ESTABLISHMENTS)

Walter L. Gojmerac and Leroy L. Peters

Propoxur, when used in pesticide products for household and commercial establishment applications, provides flushing action, contact kill, and residual control of household and commercial pests. Propoxur is often used in combination with other insecticides, such as pyrethrums or vapona, to aid in exposing insect pests to residual insecticide treatments.

Propoxur is registered for use by occupants and professional pest control operators inside and around the outside of domestic dwellings for control of a wide variety of arthropod pests. Ants, cockroaches, crickets, clover mites (*Bryobia praetiosa* Koch), firebrats (*Thermobia domestica* [Packard]), silver fish earwigs, millipedes, psocids, sowbugs, most spiders, and stored product insects are considered household nuisance pests and are controlled by the use of propoxur. Most persons associate the presence of insects inside or around their house as unsanitary and contributing to an unhealthy environment. Americans devote considerable time, money, and effort to reduce or eliminate household anthropod pests from their home.

Biting and stinging arthropods such as bees, wasps, hornets, spiders, centipedes, scorpions, chiggers, and ticks can cause dermal irritation as well as inflict painful stings or bites. Unless prompt medical attention is received, a bite or sting can be life-threatening for individuals sensitive to anthropod venom. Flies, fleas, and ticks are significant to public health because they are capable of transmitting a variety of disease organisms to humans and/or their pets. Flea problems associated with pets will be discussed separately.

For pest control in and around human habitation, propoxur is frequently formulated as an active ingredient with other insecticides or adjuvants, such as piperonyl butoxide, dichlorvos, pyrethrins, MGK 264, or methoprene. The rationale behind a combination product is to provide the consumer with an easy to use, safe, and effective product for pest problems. Propoxur is available in granular, dust, wettable powder, soluble concentrate, emulsifiable concentrate, and ready-to-use formulations, and is available to homeowners through retail outlets.

Dusts are applied using a plastic squeeze bottle (puff duster) to areas that are difficult to reach with a spray or where sprays cannot be used because of staining or other undesirable effects. Granular baits are distributed in areas where a dust or spray is not desirable, such as under appliances. Impregnated paper is used as a covering over non-food or fabric storage shelves. This paper can also be inserted into cracks and crevices where insects are known to hide. Sprays (water or oil-based) are applied along baseboards, behind and underneath appliances, fixtures, book cases, and around garbage containers. Special applicators are used for injecting spray into cracks and crevices to kill hard-to-get insects. Plastic pet collars, impregnated with propoxur, are used to control fleas and ticks on the pets.

Outside the dwelling, propoxur is applied around the foundation, especially near points of entry for arthropods (such as air vents, doors, and windows). Another major use of propoxur is spraying directly on or into wasp or hornet nests.

Propoxur Usage by Dwelling Occupants

Bennett et al. (1983) found 87 percent of homeowners surveyed had encountered insect problems within the previous year. Twenty-seven percent of those surveyed employed the services of an exterminator. This face-to-face survey contacted 958 homeowners in an urban environment in north central Indiana. Of those surveyed, 78 percent used insecticides, and 15.5 percent used a product containing propoxur.

Bennett et al. (1983) also cited other survey reports of insecticides used in homes and gardens: The percentage of homeowners who used insecticides in different States or areas were as follows: eighty-five percent in Pennsylvania; seventy-three percent in Nebraska; ninety-two and a half percent in Philadelphia, Dallas, and Lansing; eighty-nine percent in South Carolina; and ninety percent in a national survey. These reports combined garden, lawn, and in-home use into one figure.

Kamble et al. (1983) conducted a telephone survey in 1979 and 1980, surveying 937 and 1,870 heads of households in Nebraska respectively. These surveys were conducted by the Nebraska Annual Social Indicators Survey, using random digit dialing stratified to match demographic characteristics. Eighty-eight percent of the 1979 survey respondents and 81 percent of the 1980 survey respondents used insecticides. Propoxur was used by 68 percent (1979) and 31 percent (1980) of the respondents. Kamble et al. calculated that the respondents in 1979 used 3.14 lb active ingredient propoxur, and in 1980, 1.68 lb. These figures suggest that 1,879 and 1,005 lb of propoxur could have been used in Nebraska during these two years, respectively.

Gojmerac (unpublished survey, 1989a), with the assistance of selected county Extension offices, conducted a survey of homeowners in Wisconsin. This survey was biased towards adults participating in Extension programs. Respondents in this survey were asked if they (1) encountered insect problems in their homes in 1988 that required treatment, (2) what pests were involved, and (3) if they used the services of an exterminator. The most frequently encountered pests were ants, followed by boxelder bugs (*Boisea trivittata* [Say]), flies, spiders, and fleas. Cockroaches were not mentioned. The aerosol spray can was the most frequently used application method, followed by ant bait. Of 424 respondents, 47 percent encountered insect problems in households in 1988 that required control procedures. Eighty-eight percent of homeowners lived in single family homes, while the others lived in condominiums, apartments, house trailers, etc. Approximately 47 percent of the survey respondents lived in rural areas.

This similar survey was conducted in Ohio, New Hampshire, and Georgia, but with fewer respondents: Wisconsin--424; Ohio--9, New Hampshire--25, and Georgia--80. A meaningful comparison can be made between the Georgia and Wisconsin surveys of home insect problems. Respondents in Wisconsin reported having fewer insect problems in homes than in Georgia--43 percent vs 80 percent; and people in Wisconsin employed services of an exterminator less often--4 percent vs 35 percent. Responses to other questions were not dramatically different.

Because household anthropod pest problems vary from region to region in the United States, States were grouped into the Northeast, Midwest, South, and West regions (see Table 1). The southern region has the longest reproductive season for insects, as indicated by the number of propoxur applications in Table 1.

Survey data from selected States indicate households in the Northeast (18 percent) reported fewer insect problems requiring control than in the South (26 percent), where householders employ the services of the exterminator more frequently. The West and Midwest reported 21 and 22 percent respectively (Table 2). Based on these data, for any quantity of propoxur used by a householder in the northern region, perhaps 1.25 times more was used in the Midwest and 4 times more in the South.

Limitations of Survey Data

An inherent problem in pesticide user surveys of homeowners is that most can recall having a pest problem, applying a product, and usually can remember such trade names such as "Raid," "Ortho," or "Black Flag," but they were not aware of the active ingredient or ingredients of products used. Others were not aware of what the pest was, other than it was some "kind of bug." While the average person may distinguish between ants and roaches, there are occasions when a variety of pests, such as ground beetles, boxelder bugs, earwigs, or crickets enter a home and the occupant wants them eliminated. In such cases, the householder may have selected one of several over-the-counter products available.

Units Treated

Studies from the Nebraska Pesticide Use Survey (1979) stated that between 73 and 92 percent of the 88 million households in the United States use pesticides within one year. Of these, propoxur is used in over 6 million households (propoxur used by both PCO's and RTU products). Commercial propoxur use is equivalent to the treatment of 230 to 380 million square feet (assuming ten applications per year).

Commercial Uses of Propoxur

Propoxur is used extensively to control pests in commercial establishments such as in restaurants, food processing and storage areas, transportation facilities, lodging enterprises, and institutional settings, such as schools and hospitals. Pest control operators were asked to respond to a survey describing their use of propoxur in commercial sites. Corroborating information for commercial and household application patterns and rates of propoxur applied by PCO's was obtained from the National Pest Control Association (Doucet, 1989) and a private consulting firm (Tucker, 1989).

Propoxur Application by Professional Pest Control Operators

Commercial PCO's service 60 to 75 percent of all commercial establishment's pest control requirements (Tucker, 1989). Quantifying the propoxur used by PCO's is necessary to provide a comprehensive picture of total propoxur use in households and commercial establishments. Estimates of propoxur use by PCO's in commercial settings were obtained by determining the number of commercial buildings in each of the four regions and then estimating the number of buildings treated by PCO's.

Information from a private pest control consulting service and telephone survey conducted by university Extension entomologists indicated that approximately two percent of PCO's nationwide used propoxur prior to the Special Review (Tucker, 1989). This information allowed an estimate of the number of commercial buildings being treated with propoxur by PCO's by region, as well as providing estimated costs of treatment with propoxur (Table 1). The principal activities within these buildings include educational food sales and service, health care, lodging, mercantile services, offices, assembly, and other miscellaneous activities.

Table 1. Professional Pest Control Operators Use of Propoxur Products in Commercial Buildings by Region.

Region	Number of commercial buildings[1]	Number of commercial buildings using PCO service[2]	Percent of PCO's using propoxur products[5]	Number of commercial buildings treated with propoxur	Number of propoxur products applied per year[3]	Cost per application[4]	Total yearly expenditure for PCO's using propoxur products by commercial buildings ($)
Northeast	670,000	402,000 (60%)	2	8,040	6	4.50	217,080
Midwest	1,211,000	847,700 (70%)	2	16,954	8	4.50	610,344
South	1,493,000	1,119,750 (75%)	2	22,395	12	4.00	1,074,960
West	574,000	401,800 (70%)	2	8,036	10	4.50	361,620
Total commercial application per year				55,425			2,264,004
Average cost per building					$ 40.84		

[1]Source: Statistical Abstract of the United States, 1988.
[2]Source: Jeff Tucker, Entomology Associates, Houston, Texas.
[3]Estimated from survey responses. Assumed South had double the insect pressure of Northeast; Midwest and West incrementally greater pressure than Northeast due to higher temperatures and humidity in the South.
[4]Estimated from survey responses.
[5]Source: Jeff Tucker, Entomology Associates, Houston, Texas and Maxcy Nolen, Extension entomologist, University of Georgia.

Table 2. Professional Pest Control Operators Use of Propoxur Products in Households by Region

Region	Number of households	Number of households using PCO's[1]	Percent of PCO's using propoxur products[4]	Number of households in which propoxur products are used by PCO's	Number of applications of propoxur products per year[2]	Total cost per application[3]	Yearly expenditure on propoxur by households through PCO's[5] ($)
Northeast	18,588,000	3,345,840 (18%)	2	66,916	3	4.50	903,366
Midwest	21,944,000	4,608,240 (21%)	2	92,165	4	4.50	1,658,966
South	30,418,000	7,908,680 (26%)	2	158,174	6	4.00	3,796,166
West	17,847,000	3,926,340 (22%)	2	78,527	4	4.50	1,413,482
Total				395,782			7,771,980
Average per household							19.64

[1]Source: Roger Doucet, National Pest Control Association.
[2]Estimated from survey responses, assumed South had double the insect infestation than Northeast with Midwest and West heavier than Northeast but less than South. (See previous page)
[3]Assumes $4.00 per product in South, $4.50 per product in other regions. Application costs are assumed about the same for all similar pesticide products (this includes application costs plus pesticide costs. Product measurement here indicates an average of 21 oz of 1.1 percent propoxur per household application).
[4]Source: Jeff Tucker, Entomology Associates, Houston, Texas and Maxcy Nolen, University of Georgia.
[5]Assumes these costs are what the household is spending for propoxur containing products being applied by the PCO, does not include payment for PCO services.

Using this method, an estimated 55,425 commercial structures were treated with propoxur by PCO's in 1987. Professional applications were assumed to occur monthly in the South, bi-monthly in the Northeast, eight times per year in the Midwest, and 10 times/year in the West. Cost per application represents the actual insecticide cost and does not include professional application charges associated with hiring a PCO. Propoxur costs were assumed similar to those specified by the self-application of propoxur by homeowners. The assessment team estimates that approximately $2.3 million was spent on propoxur applied by PCO's in commercial building environments, or about $40.84 per year per building (Table 1).

Households use PCO's to a lesser extent than commercial establishments. Propoxur use is greatest in the South, where an estimated 26 percent of all households hire a PCO (Doucet, 1989) (Table 2). By comparison, PCO's serviced about 18 percent of the Northeast, 21 percent of the Midwest, and 22 percent of the West households. Tucker (1989) assumed that two percent of PCO's treating households used propoxur.

The assessment team provided an estimate of the number of applications by PCO's per year. Characteristically, more applications were made per year in the South (6 per year), while fewer applications were made in the Northeast (3 per year). Total yearly expenditures by households for actual propoxur applied by PCO's was estimated to be about $8.6 million, or about $19.64 per household (without considering application or service fees charged by the PCO) (Table 2).

The cost of PCO's replacing propoxur in household and commercial uses with alternative pesticides is provided in Table 3. All the pesticide alternatives listed in this table are assumed to be equally as effective as propoxur. Total expenditure for alternative pesticides applied by PCO's for household and commercial uses is estimated at approximately $10 million. The estimated cost for PCO applications of alternative pesticides in households and commercial sites is equal to propoxur usage nationwide. Use of alternative pesticides would not increase costs.

Table 3. Estimated Usage of Alternative Pesticide Products by Professional Pest Control Operators in Households and Commercial Sites by Region

Region	Number of Households using PCO's	Number of households in which propoxur products are used by PCO's[1]	Number of commercial buildings using PCO's	Commercial buildings treated with propoxur by PCO's[2]	Alternatives	Number of[3] Applications per year	Cost per[4] Application	Total cost of alternative pest products for households & buildings
Northeast	3,345,840	66,917	402,000	8,040	Chlorpyrifos Cypermethrin Pyrethrin	5 household 6 commercial	4.50 4.50	803,004 218,080
Midwest	4,608,240	92,165	847,700	16,954	Pyrethrin Fenvalerate Cypermethrin	18 household 8 commercial	4.50 4.50	1,648,870 610,344
South	7,908,680	158,174	1,119,750	22,395	Safrotin Chlorpyrifos Diazinon	6 household 12 commercial	4.00 4.00	3,796,176 1,074,960
West	3,926,340	78,527	401,800	8,036	Cypermethrin Dichlorvos	4 household 11 commercial	4.50 4.50	1,513,486 360,620
TOTAL	19,789,100	395,783	2,771,250	55,425				10,025,540

[1]Estimates as follows: for Northeast; 18 percent of total household use PCO services; 2 percent of PCO's in NE use propoxur containing products.
[2]Same estimation procedure as described above.
[3]Assumes one additional treatment of alternative product/year for household and commercial buildings by PCO's over propoxur containing products.
[4]Includes cost of alternative product only.

Usage and Comparative Efficacy

Propoxur usage in the PCO market has been decreasing over the last few years. However, recent figures indicate that propoxur's popularity is on the increase in certain areas. The homeowner market has also decreased for propoxur, though it is still an important residual insecticide. Other insecticides, such as the pyrethroids, fenoxycarb, and hydroprene have replaced propoxur.

Propoxur is still the predominant residual insecticide used in homeowner aerosol sprays. Propoxur's chief attributes are its relatively fast knockdown action and long residual on most surfaces. Propoxur is also the only effective carbamate insecticide available to consumers, making it a valuable resistance management tool for alternate usage with pyrethroids and organophosphates. Some alternatives for propoxur are as effective. Propoxur accounts for only 2 percent of the PCO usage to control cockroaches and other pests in households and commercial, industrial, and institutional areas. Cypermethrin, chlorpyrifos, propetamphos, and diazinon are currently the materials of choice by the PCO community.

Table 4. Comparative Costs of the Active Ingredients of Insecticides Used in Household and Commercial Pest Treatments When Applied by Homeowners and Pest Control Operators

	Households		Commercial
Treatment	PCO applied[1] materials/year ($)	Homeowner[2] applied	PCO applied[3]
Propoxur	$ 1.60	12.60	4.06
Chlorpyrifos	0.22	8.75	0.75
Cypermethrin	0.67	--	1.53
Diazinon	0.15	11.20	0.53
Propetamphos	1.10	--	2.79
Boric Acid	--	10.50	--
Pyrethrins	--	37.30	--

1/Cost of materials only--on the basis of four (4) one pint applications per year.
2/Cost of materials only--on the basis of 48 ounces of product, in aerosol cans or equivalent, per year.
3/Cost of materials only--on the basis of 1.75 gallons of finished product for an average 4,500 square foot commercial establishment.

Thirty-four studies were identified that evaluated the efficiency of propoxur as compared to alternatives for control of German cockroaches in apartments and single family homes. Although propoxur was directly compared to these alternatives in only 6 studies, there was sufficient information to draw general efficacy conclusions. In these tests boric acid, cyfluthrin, and cypermethrin were clearly superior to propoxur in residual and contact sprays for control of German cockroaches. Acephate, hydramethylnon, permethrin, propetamphos, and pyrethrins performed in a slightly superior manner than propoxur. Bendiocarb, chlorpyrifos, diazinon, and fenvalerate performed in an equivalent fashion to propoxur. Propoxur bait, shelf paper and impregnated tapes, chlorpyrifos impregnated tapes, and dichlorvos sprays were ineffective against German Cockroaches.

Projected Consequences of Propoxur Cancellation

The insecticidal alternatives to propoxur are chlorpyrifos, diazinon, boric acid, pyrethrins, cypermethrin, propetamphos, and safrotin. All of these alternatives are available and currently in use. Propoxur is the most effective carbamate in the homeowner market.

Should propoxur usage be discontinued by regulatory action, chlorpyrifos, bendiocarb, diazinon, and pyrethroid insecticides would be the major alternatives. Both diazinon and chlorpyrifos are presently being reviewed. Three classes of insecticides are used in and around dwellings: organophosphates, carbamates, and pyrethroids. Resistance to specific active ingredients and to classes of insecticides is documented extensively in toxicological literature. One way to delay resistance development is to rotate the use of different class of chemicals. The only other carbamate besides propoxur currently registered for use in and around dwellings is bendiocarb. If propoxur as well as bendiocarb are canceled, an entire family of insecticides would no longer be available for resistance management in household and commercial pest control.

The nonchemical methods of sanitation, exclusion, and trapping are useful in combination with chemical controls. Sanitation involves elimination of food and water sources. Exclusion includes caulking, screening, weatherstripping, and package inspection to prevent entry of pests. Electromagnetic, ultrasonic, and mechanical vibration devices have not demonstrated to be effective for cockroach, ant, or other anthropod pest control.

Three pyrethroids--cyfluthrin, fenvalerate and permethrin--and one new insect growth regulator (IGR)--fenoxycarb--have recently become available to consumers in the form of aerosol sprays. Sulfulramid, a newly developed delayed action toxicant, has also recently become available to consumers in the form of ant and cockroach bait stations.

Economic Impact

The process of assessing the economic impact of the cancellation or suspension of propoxur involved determining the extent of propoxur usage in household environments by professional pest control operators under contract. Land Grant University Extension personnel in all States except Alaska and Hawaii were asked to estimate the percentage of households in their State using propoxur, the number and cost of applications per year, the type of pest controlled, as well as similar information for EPA-registered alternative products. Extension personnel were also asked to provide a qualitative assessment of the effects on pest management for each product offered as an alternative.

Since all propoxur is imported, the quantity is a known public record, ranging annually between 500,000 to 700,000 lb of technical product. It is estimated that Johnson's Wax Company uses about

50 percent of this quantity in formulating their line of Raid™ products. It is not known if propoxur is resold to other formulators, packaged for other companies under a different trade name, or how much is manufactured into products for export to other countries.

Statistical reporting by agricultural services does not include household insecticide usage. For business reasons, formulators of insecticides are reluctant to release sales figures. However, there are occasions when the press quotes specific figures. The Wall Street Journal on June 13, 1989, reported that the "off-the-shelf" insecticide market is $500 million per year. Johnson Wax Company accounts for 42 percent of this total. Another report published in Pest Control Magazine states that homeowners spend $400 million for "do-it-yourself" pest control, and $3 billion for exterminator services. This latter report does not give a breakdown of products, chemicals, or companies involved.

The economic impact of propoxur being unavailable for use in products formulated for home and commercial application would be minimal unless the number of available products was reduced. This could create higher prices due to less competition. The registered alternatives for these sites currently include bendiocarb, boric acid, diazinon, chlorpyrifos, and the pyrethroids (resmethrin, fenvalerate, permethrin, cypermethrin, cyfluthrin, and tetramethrin). Economic losses are not expected as long as alternative insecticides are available and resistance does not develop. This analysis is contingent on the following assumptions:

(1) Propoxur quantities used were estimated for five years prior to the initiation of the Special Review of propoxur by the EPA, since the Special Review process has reduced the use of propoxur.

(2) Regional use of propoxur is projected to follow patterns established in survey results. Households in the Northeast, Midwest, and West were assumed to each have half the propoxur usage due to fewer pests and less need for a wider variety of pest-control materials than in the South.

(3) It was the assessment team's consensus that, over the short term, alternative pesticide products offered levels of pest control that were equal to or better when compared with propoxur for smaller expenditures.

(4) The use of propoxur by PCO's in commercial settings was assumed to be based on the number of commercial structures in each region. This probably underestimates the use of propoxur by PCO's, because one building may house a number of businesses, and each is treated independently by PCO's.

(5) Expenditures by households and commercial establishments for propoxur applied by PCO's reflect the cost of propoxur rather than the cost of the application services. The cost of application of a pesticide product by a PCO is therefore assumed constant for all pesticide products used in similar circumstances.

The short-run economic benefits of using propoxur for pest control at the present time are negligible because cheaper alternative materials are available. The homeowner will see little cost difference in the short run. However, if pests develop resistance to alternatives as a result of banning propoxur, some homeowners will be left with inadequate control of pests. As a result, some people will be forced to use commercial pest control services. Costs would increase from $40/year (6 to 8 spray cans) to $240/year ($20/month for PCO). (These figures were obtained from Extension specialists in Louisiana, Florida, and Nebraska.)

It is impossible to predict if, or how quickly, pest resistance would develop with each species of household pests or how many homeowners would employ the services of a PCO should propoxur no longer be available. Currently 26 percent of the homeowners use PCO services. However, if homeowners currently applying pest control measures themselves switched to a PCO, the cost would be approximately $5.3 billion ($200/year times 88.8 million households times 30 percent of households treated).

USES OF PROPOXUR ON MILITARY BASES

Jerry F. Butler

Military uses of propoxur mirror the general use of this pesticide in the private and commercial sectors. Additional uses are seen for shipboard treatments, primarily for cockroach control in ready-to-use formulations.

The military services obtain and maintain propoxur for essentially all of the labeled uses. In 1988 the U.S. Army obtained 890 lb active ingredient, which was designated for household cockroach control. The U.S. Navy procured 4,500 lb of active ingredient propoxur with designated uses at various bases for cockroach control and other household uses. The U.S. Air Force procured 1,463 lb of active ingredient, primarily for household and stored products protection.

The Air Force also designated individual pest application use as pounds of actual ingredient for each pest. The uses are as follows: household 4 lb, aerosol 19 lb, RTU solution 732 lb, suspension 36 lb, EC 331 lb, bait 71 lb, mite 6 lb, silverfish 29 lb, flea 9 lb, earwig 13 lb, ant 95 lb, wasp 39 lb, termite 8 lb, cricket 3 lb, fly 7 lb, Spider 37 lb, tick 14 lb, centipede 1 lb and scorpion 2 lb.

Logistical supplies of this chemical in 1988 indicated the amount of propoxur passing through the military system annually, with some carry-over of supplies. In 1988, 7,027 one-gallon cans of 1 percent solution and 1,547 one-gallon cans of 18.7 percent EC were in stock. In 1987, 164 five-lb. bags of 70 WP and 64 one pound jars of 70-WP were in stock. The total pounds used by the military in 1988 was 6,853 lb, which should be adjusted up by 50 percent to 10,279 lb according to Kramer (1989).

PROPOXUR USE FOR ECTOPARASITE CONTROL ON PETS

Jerry F. Butler

Arthropod parasites on pets include fleas, mites, ticks, flies, mosquitoes and other arthropods that are found either on the host as ectoparasites or are associated with the habitat of cats, dogs, and other companion animals. The most common pest species are presented in Table 5.

By definition, pet ectoparasites are found on or in the skin surface. They are important pests because they injure humans and their pets. Three categories of parasite effects are: (1) direct injury resulting from bites, blood loss, tissue consumption, venom, allergic reactions of the host or tissue damage caused by scratch reactions of the pets; (2) indirect effect, such as introduction of pathogenic organisms and the resulting disease development and accidental injury, and increased susceptibility to other stressors; and (3) other losses or effects, including peripheral effects of filth flies (pet fecal or vomit staining of the house) and secondary production losses resulting from parasite control efforts (Gerhardt, 1985). Arthropods that have the potential of transmitting pet-borne diseases to humans present special pest control problems because of the potential seriousness of the diseases they transmit.

The loss of propoxur use in insecticidal pet collar formulations for flea control is projected to have little effect on flea management since alternatives are available. Resistance of fleas to insecticides has been documented regionally, making effective ectoparasite pest management dependent on the availability of chemical families for use in a rotational pattern. Diversity in insecticide types and formulations is needed for pest management programs where pest resistance could develop.

Should the use of propoxur be lost in regulatory action, pet owners would be left with little choice other than to select a PCO or veterinary clinic for animal and household treatment of fleas. This would greatly increase the cost of flea control. Propoxur is a very effective insecticide for tick and flea control. With the loss of propoxur for tick control, there could be an increase in the number of pets and households with tick populations. Ticks are documented vectors of diseases, such as Rocky Mountain Spotted Fever, tularemia, and Lyme disease.

Effective flea control requires three different types of synchronous applications: (1) whole body treatment directly to the animal, including the use of dog and cat insecticide collars, (2) residual sprays for household infestations of adult and larval fleas, and (3) pet bedding and yard treatment with a residual spray (Koehler and Short, 1980). Treatment for the brown dog tick (*Rhipicephalus sanguineus* [Latreille]) is similar to the above, but outdoors treatment is usually not necessary. To protect animals from *Dermacentor* spp. and *Amblyomma* spp. it is necessary to treat the animals directly as well as treat the yard, run, or kennel where pets are housed outdoors. Propoxur is registered for direct applications to dogs and cats, as well as to kennels, living quarters, bedding, premises, runs, and yards.

Of the listed anthropoid ectoparasites, the two most frequently encountered groups are fleas and ticks.

TABLE 5. COMMON ARTHROPOD PESTS OF DOGS AND CATS	
Species	Common Name
Diptera	
Cuterebra spp.	bot flies
Stomoxys calcitrans (Linnaeus)	stable fly
Musca domestica (Linnaeus)	house fly
Phaenicia sericata (Meigen)	green bottle fly
Culicoides guttipennis Coquillet	sand fly
MALLOPHAGA	
Heterodoxus spp.	biting louse
Trichodectes canis (De Geer)	dog biting louse
SIPHONAPTERA	
Felicola spp.	cat biting flea
Ctenocephalides canis (Curtis)	dog flea
Ctenocephalides felis (Bouche)	cat flea
Echicnophaga gallinacea (Westwood)	sticktight flea
Pulex irritans (Linnaeus)	human flea
Pulex simulans Baker	false human flea
Nosopsyllus fasciatus (Bosc)	northern rat flea
Ixodidae	
Dermacentor occidentalis Marx	Pacific coast tick
Dermacentor variabilis (Say)	dog tick
Dermacentor andersoni Stiles	Rocky mountain wood tick
Amblyomma cajennense (Fabricius)	Cayenne tick
Amblyomma americanum (Linnaeus)	lone star tick
Amblyomma imitator Kohls	ticks
Amblyomma maculatum Koch	Gulf Coast tick
Amblyomma inornatum (Banks)	dog tick
Rhipicephalus sanguineus (Latreille)	brown dog tick
Ixodes scapularis Say	.black-legged tick
Ixodes dammini Spielman, Clifford, Tiesman, Corwin	deer tick
Ixodes pacificus Cooley and Kohls	CA black-legged tick
ACARINA	
Cheytiella spp.	mange mite
Sarcoptes scabiei (De Geer)	itch mite
Demodex canis Leydig	dog follicle mite
Otodectes cynotis (Hering)	ear mite of dogs & cats
Trombicula spp.	chigger
Eutrombicula spp.	chigger
Notoedres cati Hering	cat mange mite
CULICIDAE	
Aedes spp.	mosquitoes
Culex spp.	mosquitoes

Fleas Biology and Control

Seven species of fleas have been associated with humans and domestic animals. Adult fleas are small (1/16"), dark, reddish-brown, wingless, blood-sucking insects. Their bodies are laterally compressed, permitting easy movement between the hairs or feathers of the host. Flea legs are long and adapted for jumping. The body is hard, polished, and covered with numerous hairs and short spines directed backward. The adult stage of the flea is the only life stage that's ectoparasitic, or adapted for sucking blood. It lives off the warm blood of the host.

Five species of fleas are commonly found in Florida (Layne, 1971) and the other Gulf Coast States. During the dry season, this region and California have demonstrated more severe flea problems than the northern regions of the United States. Regulatory actions that reduce flea management options will have their most severe effect on southern and western States, with a real potential for increased parasite and disease transmission.

Female fleas lay small, white eggs on their host's hair coat, feathers, nest or bed. Freshly laid eggs fall from the host onto the ground, floors, bedding, or furniture. A high humidity and temperature enhance egg deposition and survival (Knapp and Scheibner, 1985). Some species of fleas can lay up to 500 eggs over a period of several months. The eggs hatch into white worm-like larvae, which feed on particles of dead, dried animal or vegetable tissue generally present in their host's bedding, as well as in carpets.

A common food source for flea larvae in pet bedding is the dried, undigested blood present in fecal pellets from the adult flea feeding on the host. The third larval stage completes development in 7 to 14 days, and the larva spins a cocoon in which it pupates. In approximately one week the adult fleas emerge and search for hosts and a blood meal.

Adults fleas are able to live up to 100 days after emerging without feeding. The adults must feed on blood prior to reproduction, and they remain in close proximity to their hosts thereafter. Heaviest flee populations in houses are found in proximity to areas where pets rest for prolonged periods, such as near the pet's bedding. Once established in a home, fleas feed on humans for a blood meal, with the frequently attacked parts of the body being the ankles and lower portions of the legs. Women are more frequently attacked by fleas than men (Harwood and James, 1979).

The entire life cycle of a flea requires two weeks to two years. Hot, wet summer months favor egg-laying. Hot, dry periods give maximum larval and adult production. August to September usually produces the greatest adult flea populations, resulting in both complaints and inquiries (Harwood and James, 1979).

Flea-infested pets are recognized by their extensive scratching behavior. If untreated, pets' coats can become roughened. Subsequently, a secondary dermal bacterial infection often develops on the coat that can be mistaken for mange.

Fleas in a house are annoying to humans because their bites cause intense itching, often resulting in a secondary dermal infection. Flea bites are recognized on human skin as a small red spot where the flea has inserted its mouthparts and injected salivary fluids. Surrounding this spot is a red halo, accompanied by a slight swelling. Some people have no dermal reaction to flea bites; others are moderately sensitive; and a small percentage will suffer severe allergic reactions. Fleas have the potential to serve as vectors for the human diseases of plague, typhus, tularemia, and various viral diseases (Harwood and James, 1979).

Non-pesticidal premise control includes thorough and frequent vacuum cleaning of the house. In extreme cases, steam cleaning of carpets, infested furniture, pet baskets, and other flea habitat is recommended. Dirt that is collected in vacuum cleaners with disposable bags should be discarded immediately to destroy fleas and flea larvae.

Tick Biology and Control

Ticks may be the most detested pests of humans and pets, and are parasites that require a blood meal from their host in all of their life stages (Dimant and Strickland, 1965). Several species of ticks attack dogs, which may become severely infested, while cats are infrequently infested. Ticks not only annoy humans, but pose a real threat in disease transmission with such diseases as Rocky Mountain Spotted Fever, Colorado tick fever, Lyme disease, and tick paralysis (Hoogstraal, 1979). Four of the most important species include the American dog tick (*Dermacentor variabilis* [Say]), the brown dog tick, the deer tick, and the lone star tick (*Amblyomma americanum* [Linnaeus]). The American dog tick, the black-legged tick, and the lone star tick attack a wide variety of hosts, including humans. The brown dog tick rarely bites humans, but is a household pest in homes with dogs (Benbrook, 1963).

The American dog tick is also a common pest of pets and humans. This tick is a three-host tick, seeking a different host for each blood meal. Adult male and female ticks are encountered by sportsmen and others in outdoor activities. Dogs are the preferred host for the adult American dog tick, though ticks will feed on other warm-blooded animals. Ticks in the nymphal stages attack small mammals and birds. Details of the life history of this anthropod are addressed by Diamant and Strickland (1965).

The brown dog tick seldom attacks animals other than dogs. Once established in the house, it is found most abundantly in areas where dogs are kept in or around the house. The brown dog tick is not normally known to transmit diseases to humans, but may transmit rickettsia and babesia as well as other protozoans. In the house, the brown dog tick hides off the pets and moves to the sleeping animal to feed, similar in behavior to a bed bug. The life history of this tick is described by Dimant and Strickland (1965) and Harwood and James (1979).

The black-legged ticks are three-host ticks. Both adults and immature forms feed on many mammals, birds, and reptiles. These species of ticks are found throughout a large area of the United States. Black-legged ticks are vectors of Lyme disease (Piesman, 1988; Burgdorfer, 1985), feeding on mice, as larvae, and on larger animals as adults.

Ticks should be removed from pets and humans as soon as noticed. If the attached tick's mouthparts are broken, the parts left in the skin may transmit disease or cause secondary infection. Ticks may easily be removed by grasping the mouthparts as close to the skin as possible with forceps, then pulling the tick firmly and evenly. A small amount of tissue should be seen attached to the mouthparts after the tick is removed.

Pesticidal control of ticks may require treatment of both the pet and the area. If heavy tick infestation occurs, it is necessary to treat pets, home, and yard simultaneously. The types of insecticides and the methods of application will vary, depending on the kind of premise being treated.

People entering tick-infested areas should keep clothing buttoned, shirts inside trousers, and pants inside socks and/or boots. They should not sit on the ground or on logs in bushy areas. Brush should be cleared or burned along frequently traveled areas. Repellents such as DEET (diethyl toluamide), methyl phthalate, dimethyl carbamate or ethyl hexanediol will protect exposed skin.

Ticks will, however, crawl over treated skin to feed on untreated parts of the body (Nolan, 1988; Koehler and Short, 1980).

The Use of Propoxur on Pets

Use of propoxur for controlling fleas and ticks on dogs and cats is formulated primarily as collars, dips, and washes. The most common homeowner use pattern within the household is the collar formulation, according to the 1989 NAPIAP survey (Butler et al., 1989). Collars are applied to the animals for different durations and at different formulation rates, depending on whether cats or dogs are being treated. Applications of propoxur on pet collars represent 56 percent of veterinarian use. Dips are the next most common type of treatment (Kamble and Braulick, 1983).

Pest populations of fleas and/or ticks present on the animal will vary with geographical regions of the country. In general, the Southern and Gulf Coast regions share high populations of both fleas and ticks for extended periods of the year and require continuous treatment for flea control (Table 6). In the South, including Arizona and California, ticks and fleas are a problem for at least nine months of the year, with major flea populations peaking in the late spring and early fall or during dry seasons.

The estimate of the extent of treatment for flea and tick control is based on the numbers of animals present in the United States. According to 1988 pet population surveys by the American Veterinary Medical Association (AVMA) (Table 6), the United States had about 52 million dogs and 55 million cats, for a total of 107 million cats and dogs in U.S. households. This is approximately 59 dogs and 62 cats per 100 households, or a total of approximately 120 cats and dogs per 100 households.

Pet owners in the South will treat a minimum 60 percent of their animals at least once per year. Kamble and Braulick (1983) reported that 13 percent of dogs and cats in Nebraska were treated with propoxur by veterinarians. We estimate up to 20 percent of the animals are treated for flea and tick control in the North at one treatment per year, while animals in the Gulf Coast region require two to three treatments to control pet pests (Gojmerac, 1989).

Table 6. U.S. HOUSEHOLD CENSUS DISTRIBUTION FOR 1986 WITH PET POPULATION CHARACTERISTICS ADAPTED FROM 1989 (X 1000)

REGION	HOUSEHOLDS[a]	PETS	DOGS	CATS	PEST SEASON (Months)
Northeast	18,588	22,386	10,960	11,425	4-12
Midwest	21,944	26,428	12,939	13,488	2-6
South	30,418	36,633	17,935	18,697	9-12
West	17,847	21,493	10,523	10,970	3-6
U.S. TOTAL	88,797	106,942[b]	52,359[b]	54,583[b]	4-9
Pets per household		1.20	0.59	0.62	

[a] National Data Book and Guide to Sources Statistical Abstract of the U.S. 1988, 108th Edition.
[b] U.S. Pet Population as Presented by the AVMA 1989.
Source: National Data Book and Guide to Sources Statistical Abstract of the U.S. 1988, 108th Edition.

The principal dog and cat pesticide labels used by home owners (Cutter Laboratories, Haver-Lockhart Laboratories, Haver, Mobay Corporation, Zoecon Corporation) place 9.4 percent active ingredient of propoxur and 90.6 percent inert ingredients in tick and flea collars for cats. The net weight for cat collars is 0.29 oz ingredients, with 0.03 oz of technical compound per formulated collar. Dog collars are heavier at 1.2 oz ingredients, with 0.11 oz active ingredient per formulated collar. Small dogs have collars with 0.7 oz ingredient or 0.07 oz of technical compound per formulated collar. Effective use of propoxur for pest control, according to labels, is 20 to 21 weeks.

Pet sprays are formulated at 0.25 percent propoxur. Cats are treated for 5 seconds and dogs for 20 to 30 seconds as needed, but not more often than every 7 days. Dip formulations are supplied as 50 percent active ingredient packs at 1/3 oz, to be diluted in 1 gallon of water. Treatments are not to be applied more often than weekly intervals. Insecticide shampoo formulations are utilized by both homeowners and veterinarians and are available at 0.125 percent active ingredient. Both dog and cat treatments are allowed twice weekly. Of the 12,000 to 15,000 lb of propoxur produced, 3 to 4 percent is estimated for use on cats and dogs (EPA, 1987c). Annual usage of propoxur for direct application to dogs and cats is estimated at about 475 lb/year.

Resistance of Fleas and Ticks to Insecticides

Flea resistance to insecticide treatments was first seen in 1952 (Kilpatrick and Fay, 1952). Since then, resistance has been documented to chlorpyrifos, malathion, bendiocarb, propoxur, and carbaryl (El-Gazzar et al., 1988; El-Gazzar et al., 1986; Gratz, 1980). The regions where this resistance developed was noted by the above authors, as well as Osbrink et al. (1986).

Tick resistance to insecticide treatments was evaluated for the American dog tick, the lone star tick, and the brown dog tick by Koch and Burkwhat (1983 and 1984). Propoxur was the most effective material tested for control and rotenone was the least effective. Propoxur is one of only a few carbamate insecticides labeled for ectoparasite pest-resistance management strategies. Management of resistance by multiple attack requires the use of compounds affecting insects that have different mechanisms of resistance, and propoxur, carbaryl, and bendiocarb, each with their unique labeling, are the carbonate components of these management strategies (Georghiou, 1983). Removal of these insecticides may adversely effect human and animal health due to direct damage and disease transmission when control fails.

Economic Impacts of the Loss of Propoxur for Pest Control on Pets

The economic impacts of canceling propoxur registration for flea and tick control will be evaluated by the change of cost to implement alternative controls. Because flea and tick pest season lengths differ from North to South (see Table 6), the economic impacts will be considered separately for flea and tick control. The economic impacts of pest resistance will also be considered.

Several flea-control alternatives to propoxur collars exist. The most likely alternative for flea control is the chlorpyrifos collar (Brassard and Hopkins, 1989). Both propoxur and chlorpyrifos collars are effective for one month. The flea seasons in the North and South are four and nine months, respectively. The price of a propoxur collar is $5.94, chlorpyrifos is $4.80 (Brassard and Hopkins, 1989). Thus, the annual flea-control costs using propoxur in the North and South are $23.76 and $53.56, respectively, while the annual flea control costs using chlorpyrifos collars in the North and South are $19.20 and $43.20, respectively. The change in annual flea control costs in the North is a decrease of $4.56, and in the South of $10.36. The number of pets (dogs and cats) treated for fleas in the North and South is 14 million and 22 million, respectively. Aggregate annual flea-control cost change is estimated to be a cost decrease of $63.8 million in the North and $228 million in the South, or $298.8 million nationally.

No equally effective alternative to propoxur collars exists for tick control. The alternative to propoxur for tick control collars is a permethrin dip. An average permethrin dip uses 4 oz of concentrated material. The price of 4 ounces of permethrin dip is $5.82 (Brassard and Hopkins, 1989). The annual tick-control costs, using permethrin dip, are estimated to be $23.28 in the North and $52.38 in the South. Thus, the change in annual tick control costs is a decrease of $0.48 in the North and $0.18 in the South. The aggregate impacts are cost decreases of $6.7 million in the North and $4 million in the South, or $10.7 million nationally. Note, though, that dips have no residual control; dips only control the ticks that are on the pet at the time the dip is administered, while the propoxur collar has a prolonged contact period that protects the pet. Therefore, the risk of pet owners acquiring a tick-borne disease, while being unknown, may increase when using a shampoo or dip.

Flea and tick resistance to insecticides has been documented. The extent to which resistance spreads is not yet understood. Should resistance develops to a national scale, the alternative to insecticidal collars is the flea dip, with a product that can only be administered by a veterinarian. The estimated cost of a veterinarian-administered flea dip is $35.00 ($15.00 for the veterinarian's diagnosis, $20.00 for the dip). However, because of the high cost of this treatment, the number of treatments is assumed to decrease by 50 percent, or 2 treatments in the North and 4.5 treatments in the South. The annual flea and tick control costs, if a resistance problem develops, is estimated to be $70.00 in the North and $157.50 in the South. The change in the annual flea and tick control cost increases are estimated to be $647 million in the North and $2.3 billion in the South, or $2.9 billion nationally.

The cancellation of propoxur is estimated to decrease both flea and tick control costs by $298.8 million and $10.7 million, respectively. However, without the prolonged control of an effective collar, such as a propoxur collar, risks of tick-borne disease transmission may increase. If resistance becomes a national problem, flea and tick control costs are estimated to increase by $2.9 billion.

Alternative Pest Management Options for Ectoparasites

Carbaryl, chlorpyrifos, dichlorvos, naled, phosmet, pyrethrins, and tetrachlorvinphos are all registered for ectoparasite control in pets. Each active ingredient has its own unique limited registration, but could replace certain usages of propoxur. A permethrin-impregnated collar under development, Blockade™ (DEET and fenvalerate) was reintroduced in the market for flea and tick control on pets. There is a methoprene pet spray under development that has demonstrated persistent ovicidal activity on flea eggs.

The following nonchemical pest management options should be performed on a frequent basis: vacuuming pet resting and sleeping areas; laundering of bedding; inspecting and grooming pets; and changing kitty litter. All of these actions aid in the control of fleas and ticks. Adding baking soda to kitty litter facilitates the control of fleas. Exclusion techniques, such as denying pets access to areas under the porch or house and restricting contact with other dogs and cats, are also helpful. None of these techniques alone will control fleas.

Flea control involves a holistic approach, which includes both chemical and nonchemical treatments. Chemical treatments should involve not only treatment of pets with impregnated collars or other residual treatments, but also treatment of yards and household premises with residual insecticides, such as chlorpyrifos, methoprene, or propetamphos.

The price of pet products may have greater variability resulting from the place of purchase (pet store, department store, grocery store) than from different active ingredients. However, propoxur generally tends to be more expensive than the alternatives. Effective products are available to pet owners for flea and tick control. These include flea and tick collars, dips, aerosol sprays, dusts, and shampoos.

BENEFITS ANALYSIS FOR PROPOXUR USE FOR NUISANCE OUT-OF-DOORS PESTS

Jack L. Bagent and Jerry F. Butler

Propoxur is available in homeowner labels and pest control operator (PCO) formulations for control of stinging Hymenoptera (wasps, hornets, bees, yellow jackets), ants, and miscellaneous invertebrate pests (centipedes, clover mites, cockroaches, crickets, earwigs, millipedes, moths, scorpions, sowbugs, pillbugs, and spiders). Most of the pests in this group are nuisance pests, which means people object to their presence in and around the home environment. Ants, bees, wasps, hornets, yellow jackets, spiders, and scorpions bite and sting, which in some situations can be a health hazard. Approximately 40 people are known to die each year in the United States from bee or wasp stings. Carpenter ants can cause structural damage to homes.

Comparative Efficacy

For control of ants, stinging hymenoptera (except aerial nesting species), and miscellaneous invertebrate pests, propoxur is only one of many efficacious chemicals available to consumers and PCO's.

Propoxur is the pesticide of choice for use against aerial nesting wasps, hornets, and yellow jackets. In one efficacy test, propoxur and bendiocarb aerosol sprays had the fastest knockdown of any material tested. Fast knockdown is an important attribute in wasp and hornet sprays. Without it, the applicator is at risk of being stung. In several efficacy tests, formulations containing resmethrin, methylene chloride/fluoromethane, acephate, chlorpyrifos, and cyfluthrin were effective in destroying the nest, but had little or no knockdown effect. Several authors (including Butler and Gojmerac), however, believe that resmethrin, pyrethrins, and methylene chloride/fluoromethane formulations also possess rapid knockdown.

Availability of Alternatives

The following are available alternatives for the general outdoor uses of propoxur. The alternative insecticides for control of wasps and hornets are resmethrin, diazinon, and chlorpyrifos. These alternatives are widely available. Bendiocarb, carbaryl, and malathion share certain outdoor labeling against nuisance pests, and could serve as alternatives to propoxur.

Extent of Usage

<u>Active Ingredient Basis</u>: (1985 usage estimates): Between 90,000 and 150,000 lb active ingredient propoxur was used in this outdoor/garden market. This amount was equally divided between general outdoor insect control and wasp and hornet control. This represents 15 to 25 percent of U.S. propoxur usage.

<u>Units Treated</u>: Approximately 12 to 18 million aerosol cans of propoxur are used yearly. Assuming that the average user applies 32 oz per year, propoxur aerosol formulations will be used in 6 to 9 million households for outdoor pest control. Ready-to-use liquid sprays and baits is less widespread than aerosol cans. These sprays and baits are used by 3 to 5 million households.

<u>New Chemical Controls</u>: Several yellow jacket baits are currently being evaluated. Several new products containing methylene chloride and chlorofluorocarbons are available to PCO's for control of aerial nesting wasps and hornets. A new wasp and hornet spray, containing detergent as an active ingredient, is currently under development.

Nonchemical Control Methods: Sanitation, exclusion, landscaping, and construction changes are useful when combined with chemical controls. Many of these pests are effectively managed by eliminating conditions near tile structures that allow the insects to harbor and build up to large numbers. Nonchemical control methods are usually ineffective in controlling wasps and hornets.

Trends in Usage: Propoxur use for outdoor pest control has remained constant during the last several years.

Usage of Major Alternatives: There are many effective alternatives for propoxur in the outdoor pest control market. Alternatives for the wasp and hornet segment of the market that are currently available are less effective than propoxur for outdoor pest control.

Usage Projection: Without propoxur, the use of chlorpyrifos, diazinon, pyrethrins, and resmethrin will increase. Use of these products will decrease costs by $2.50 to $4.40 per year. Users of wasp and hornet control products will also experience decreased costs; however, because the alternatives are not as effective, these pests may disrupt recreational activities by stinging more people. The loss of propoxur may result in increased hospitalizations of allergic individuals (less than one percent of U.S. population are allergic) and could increase the number of deaths from individuals being stung.

In the absence of propoxur, all of these outdoor pests (except wasps and hornets) can be adequately controlled by any of the alternatives and at a lower per unit cost. In the case of hornets, yellow jackets, and aerial nesting wasps, the reduced efficacy of alternatives will pose a higher risk of getting stung for the applicator.

COMPARATIVE COSTS

Treatment	Cost per 32 ounces of aerosol
Propoxur	$10.24
Chlorpyrifos	5.80
Diazinon	7.50
Pyrethrins	6.10
Resmethrin	7.70

Propoxur Use In Mosquito Control

At one time propoxur was one of the primary insecticides used for mosquito abatement programs in the United States. However, a survey by the American Mosquito Control Association in 1987 indicated that there were only a few thousand pounds of propoxur used for this purpose in the entire continental United States that year. Mosquito abatement districts use 5,000 to 6,200 lb of active ingredient propoxur each year (Brassard, 1989b). Propoxur is applied over approximately 100,000 acres, mostly as a larvicide. Malathion and naled were the primary insecticides of choice used as a mosquito adulticide against organophosphate-susceptible mosquitoes. Propoxur is the insecticide of choice for control of organophosphate-resistant mosquitoes in the San Joaquin and Sacramento Valleys in California. Resmethrin and natural pyrethrins can be used in place of propoxur. However, these two insecticides have some limitations that make them less desirable than propoxur. Resmethrin is not labeled for use on cropland, therefore, it can be applied only to nonagricultural areas. Also, some populations of mosquitoes have demonstrated resistance to resmethrin. The pyrethrins have been in short supply for almost a decade, and there is no evidence that the supply will increase. Propoxur could play an important role in the management of mosquito resistance.

Available insecticidal alternatives for propoxur in mosquito control programs are malathion, naled, fenthion, chlorpyrifos, pyrethrins, and resmethrin.

Nonchemical controls involve modifying habitats to eliminate standing water; breeding and releasing mosquito-eating fishes (for example: Gambusia spp.); unleashing predator mosquitoes; enhancing naturally occurring pathogens; and installing home window screening. The methods are most effective when used in combination with chemical controls. Researchers are currently conducting efficacy tests on two new pyrethroids insecticides, ETOC and lamda-cyhalothrin (Karate). Preliminary tests with ULV foggers showed excellent control of adult mosquitoes at dosages of 0.0002 and 0.00005 lb per acre respectively. Alternatives to propoxur for use as an adulticide for mosquito control are malathion and resmethrin, both of which are readily available, and pyrethrins, which are currently in short supply.

Extent of Usage of Propoxur

Active Ingredient Basis: (1987 usage estimates)

California	5,200 lb ai
Other	1,000 lb ai
TOTAL	6,200 lb ai

This represents approximately one percent of U.S. propoxur usage. Most propoxur is applied by aircraft in a low volume spray.

Units Treated:	Estimated Acre Treatments (current year basis)
California	75,000 - 100,000
Other	14,000

Comparative costs:

Treatment	Costs Per Acre Per Application
Propoxur	$2.50[a]
Pyrethrin	0.62[b]
Resmethrin	0.34[b]

[a] includes $1.25 in aerial application cost.
[b] includes $0.14 in ground aerosol application cost.

BENEFITS ANALYSIS FOR PROPOXUR USE IN EDIBLE PRODUCT AREAS OF FOOD HANDLING ESTABLISHMENTS

Maxcy P. Nolan, Jack L. Lloyd, and Walter L. Gojmerac

Use: Edible Product Areas of Food Handling Establishments
Major Pests Controlled: Cockroaches
Chemical Alternatives (Major Registered Chemicals): Cyfluthrin, chlorpyrifos, bendiocarb, diazinon, and boric acid.

New Chemical Controls: Cyfluthrin is the newest insecticide registered for use in food handling establishments.

Nonchemical Control Methods: Sanitation, exclusion, and trapping are useful when combined with chemical controls. Sanitation involves elimination of food and water sources. Exclusion includes caulking, screening, weatherstripping, and package inspection to prevent entry of pests. Electromagnetic, ultrasonic, and mechanical vibration devices are ineffective for the control of cockroaches.

Recommendation Summary: Primary Recommended Chemicals:

Chemical Recommendations		Application Type				
		C+C*	Spot	General	Space	Bait
Acephate	6	Yes	Yes	--	--	--
Bendiocarb	7	Yes	Yes	--	--	--
Boric acid	7	Yes	--	--	--	Yes
Chlorpyrifos	9	Yes	Yes	--	--	Yes
Cyfluthrin	5	Yes	Yes	Yes	--	--
Diazinon	9	Yes	Yes	--	--	--
Dichlorvos	1	Yes	--	--	Yes	Yes
Fenvalerate	4	Yes	Yes	Yes	--	--
Hydramethylnon	6	--	--	--	--	Yes
Propetamphos	7	Yes	Yes	--	--	--
Propoxur	6	Yes	--	--	--	Yes
Pyrethrins	2	Yes	Yes	Yes	Yes	--
Resmethrin	1	Yes	Yes	Yes	Yes	--
Silica gel	3	Yes	Yes	--	--	--

* Residual crack and crevice application.

Performance Evaluation

Pest Damage: In food handling establishments, cockroaches are undesirable because they have the potential for carrying and spreading various disease organisms that can contaminate food in preparation. In addition to contaminating foods, the presence of cockroaches in restaurants and cafeterias is aesthetically unappealing to customers and can have an adverse impact on business. Furthermore, most communities have health codes that severely limit the severity of cockroach infestations allowable in food handling establishments.

Comparative Efficacy: Cyfluthrin is rapidly becoming the predominant residual insecticide used in food handling establishments (FHE's) for control of cockroaches, and it has largely replaced propoxur and several other insecticides for this use. PCO's are also using chlorpyrifos, and, to a

much lesser extent, diazinon, bendiocarb, resmethrin, and pyrethrins in FHE's. Propoxur, once widely used by FHE's, now occupies less than five percent of the FHE insecticide market.

Cyfluthrin is perceived by industry experts as being the most efficacious compound registered for use in food areas of FHE's. In efficacy studies, cyfluthrin and boric acid provided the highest level of control of German cockroaches in apartments and single family homes. Acephate, hydramethylnon, propetamphos and pyrethrins appear to be slightly superior to propoxur, while bendiocarb, chlorpyrifos, diazinon, and fenvalerate are roughly equal to propoxur in efficacy against German cockroaches.

Comparative Costs:

Treatment	Cost of material per treatment[1] ($)
Propoxur	2.11
Cyfluthrin	0.88
Chlorpyrifos	0.39
Bendiocarb	1.37
Diazinon	0.28
Resmethrin	0.63

[1] An average treatment requires 0.91 gallons of finished spray for a 4500 square foot facility. At 1.1 percent finished spray concentration, one pound active ingredient treats approximately 56,000 square feet.

Food handling establishments include restaurants, food processing plants, and supermarkets. Edible product areas are places that receive, serve, store, prepare, and process food. The use of propoxur is limited to crack and crevice application.

Availability of alternatives: The alternatives for propoxur are numerous, widely available, and efficacious.

Extent of Usage

Active Ingredient Basis (1989 usage estimates): Between 15,000 and 25,000 lb active ingredient is used on a yearly basis and applied by contract application or directly employed PCO's. Propoxur only accounts for 5 percent or less of the food handling establishment market. Propoxur also represents less than 5 percent of the total U.S. pesticide usage for food handling areas.

Units Treated: Between 18,000 and 31,000 FHE's are treated each year (assuming 4,500 square feet per establishment and 10 applications per year).

Trends in Usage: The usage and importance of propoxur for food product areas of food handling establishments has been decreasing. This decrease has occurred, in part, because cyfluthrin has replaced propoxur.

Usage of Major Alternatives: Cyfluthrin and chlorpyrifos are the predominant residual insecticides in food handling establishments. Other commonly used insecticides are diazinon, bendiocarb, propetamphos, hydramethylnon, acephate, and boric acid.

BENEFITS ANALYSIS FOR PROPOXUR USE ON LAWNS AND TURF

Jack L. Bagent

Although several alternatives to propoxur are available for insect control on lawns and turf, several insects are effectively controlled by propoxur. This is especially true of a number of pests that occur on the U.S. Gulf Coast. Chinch bugs, for example, are effectively controlled by propoxur, and survey results indicate that propoxur is one of the preferred insecticides for controlling these insects. Propoxur is also effective against sod webworms and ticks. However, there are other alternatives to propoxur for this particular use, and it may not be missed as severely. Crickets, which are often found inside as well as outside buildings, are effectively controlled by propoxur. Recent research indicated that some resistant mole crickets were also very effectively controlled by granular formulations of propoxur (Pollet, 1989). Approximately 12,000 to 30,000 lb of active ingredient propoxur are used on lawns and turf annually (Brassard, 1989b).

Major registered insecticides that are alternatives for propoxur for ornamental, lawn, and turf pest control are bendiocarb, carbaryl, chlorpyrifos, diazinon, ethoprop, isazophos, isofenphos, and trichlorfon.

Nonchemical control options involve selection of resistant strains of grass as a method of reducing turf pest problems. Reduced amounts of nitrogen, or the use of water insoluble nitrogen, can reduce chinch bug and sod webworm damage. Control of thatch reduces the numbers of these insects and increases the effectiveness of pesticide application. In general, turf kept healthy by proper irrigation, fertilization, thatch removal, mowing (at correct height), etc., will be less vulnerable to pest damage and may eliminate the need for insect control completely.

Several pyrethroid insecticides have recently been registered for use on lawns. These include bifenthrin, fenvalerate, fluvalinate, and permethrin.

In 1985 the estimates for propoxur use on lawns and turf was between 12,000 and 30,000 lb active ingredient. It is estimated that the equivalent area treated with propoxur is between 2,100 and 5,300 acres per year. This would represent 2 to 4 percent of U.S. propoxur usage. The usage of propoxur for ornamental lawns and turf has decreased in the last several years.

COMPARATIVE COSTS:

Treatment	$/application/acre
Propoxur	121.00
Carbaryl	47.11
Chlorpyrifos	27.50
Isofenphos	46.50
Diazinon	24.34
Isazophos	N/A
Bendiocarb	28.29
Ethoprop	53.35
Trichlorfon	23.03

Usage of Major Alternatives: There are many effective alternatives for propoxur in the lawn and turf market. According to 1982 data diazinon, isofenphos, and trichlorfon were the leading insecticides in the turf market. Industry sources report that isazophos, introduced in 1987, has claimed a substantial share of this market and will continue to grow. Without propoxur, the use of diazinon, isofenphos, isazophos, and chlorpyrifos should all increase.

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